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Time-series validation of MODIS land biophysical products in a Kalahari woodland, Africa

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Monthly measurements of leaf area index (LAI) and the fraction of absorbed photosynthetically active radiation (f_{APAR}) taken at approximately monthly intervals were collected along three 750 m transects in a Kalahari woodland near Mongu in western Zambia. These data were compared with MODIS NDVI (MOD13, Collection 3) and MODIS LAI and f_{APAR} products (MOD15, Collection 3) over a 2 year period (2000–2002). MODIS and ground-measured LAI values corresponded well, while there was a significant bias between MODIS and ground-measured f_{APAR} even though both MODIS variables are produced from the same algorithm. Solar zenith angle effects, differences between intercepted and absorbed photosynthetically active radiation, and differences in measurement of f_{APAR} (photon counts versus energy) were examined and rejected as explanations for the discrepancies between MODIS and ground-measured f_{APAR}. Canopy reflectance model simulations produced different values of f_{APAR} with the same LAI when canopy cover was varied, indicating that errors in the estimation of canopy cover in the MODIS algorithm due to the land cover classification used are a possible cause of the f_{APAR} discrepancy. This is one of the first studies of MODIS land product performance in a time-series context. Despite a bias in f_{APAR}, our results demonstrate that the woodland canopy phonology is captured in the MODIS product.

1. Introduction

One of the important uses of satellite observations of the Earth is to monitor seasonal changes of vegetation (e.g. Goward *et al.* 1985, Justice *et al.* 1985, Reed *et al.* 1994, Moulin *et al.* 1997, Chidumayo 2001). Seasonal variations in leaf area index (LAI) and the fraction of absorbed photosynthetically active radiation (f_{APAR}) are vital to determine landscape water, energy and carbon balances, as well as in the detection of long-term climate change (Potter *et al.* 1993, Churkina and Running 1998). As such, it is useful to examine the accuracy of LAI and f_{APAR} from the MODIS (Moderate-Resolution Imaging Spectroradiometer) algorithms against surface measurements over a multi-year period at a single site that experiences significant seasonal variations in these variables.

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In any exercise where there are comparisons made between biophysical variables measured using multiple methods, it is very important to understand how each variable is defined as well as to examine the effects of possible error sources affecting the measurements.

There are multiple approaches to measuring LAI, and along with them are multiple subtly different definitions of LAI itself. Barclay (1998) describes five common measurement approaches for determining LAI and finds that each measurement approach results in a different definition of LAI. His five definitions are:

1. total LAI based on the total outside area of the leaves, taking leaf shape into account, per unit area of horizontal land below the canopy;
2. one-sided LAI is generally defined as half the total LAI, even where the two sides of the leaves are not symmetrical;
3. horizontally projected LAI is the area of 'shadow' that would be cast by each leaf in the canopy with a light source at infinite distance and perpendicular to it, summed up for all leaves in the canopy per unit area of horizontal land below the canopy;
4. inclined projected LAI, 'silhouette' LAI, or effective LAI, represents the projected area of leaves taking into account individual leaf inclinations; and
5. a variation on number 4 where overlapping leaf areas are counted only once.

6.   Conclusions

This study of seasonal variation in MODIS LAI and f_{APAR} products shows that both products describe the pattern of seasonal vegetation change observed at Mongu. However, we find that while the MODIS LAI product matches observed values of ground-measured effective LAI with a small offset, there are significant differences between the MODIS f_{APAR} product and ground-measured f_{IPAR}.

The examination of the relationship between NDVI and f_{IPAR} indicated that variations in leaf optical properties may be an important source of error in retrieving biophysical variables (Goward and Huemmrich 1992, Huemmrich and Goward 1997). The spatial and temporal variability of leaf optical properties is not well known. Improving the accuracy of biophysical variable retrieval may require a systematic study of the variability of leaf optical properties.

This study examined the effects of SZA on f_{IPAR} indirectly; future validation studies should directly address this issue. Data-collection protocols should include f_{IPAR} measurements at multiple times in a single day at a single site to test the effects of SZA on f_{IPAR}.

Simulations from a simple canopy reflectance model suggest that another possible cause of the differences between MODIS and ground-measured f_{IPAR} may be due to errors in estimating canopy cover in the MODIS algorithm. The canopy cover differences are due to the classification of Mongu as a savannah where the assigned fractional canopy cover in the algorithm was less than the observed coverage.

The results of this analysis clearly show that success in retrieving one biophysical variable does not ensure success with other variables, even when there is a physical link between the variables as there is between LAI and f_{APAR}. This means that validation efforts must be made for all satellite data products.